SATURATION ABSORPTION OF THE IR-FIR RADIATION IN SEMICONDUCTORS AND ITS TECHNICAL UTILIZATION

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Semiconductor materials, which widely use in IR-FIR laser technology, change their properties under the action of the laser radiation. Nonlinear absorption (saturation) of these materials leads to the nonlinearity of the detectors, gives the possibility of the nonlinear optic elements construction, influences on the work of the FIR semiconductor lasers etc. The process of the saturation absorption is able to have a different nature.

The paper is devoted to study of the saturation absorption in semiconductors with the degenerate valence band structures and its application. The linear absorption in this case is due to the following mechanisms: direct (. heavy-to-light hole) intraband transitions, nondirect (Drude) intraband transitions and the absorption on the lattice oscillation.

We shall consider the mechanisms of the saturation absorption in the case of intraband (heavy-to-light hole) transitions. There are two mechanisms of it. One of them is related to the dipole moment of the system and it becomes significant when the probability of the absorption of a photon is comparable with the probability of the loss of the dipole moment phase /1,2/. This mechanism identifies to the suturation absorption in two levels system, which is well known in the gases as Raby oscillations. In our case, the role of two levels plays the initial and final states of a hole excited by light. The process of the loss of dipole moment phase in semiconductors can be determined by any kind of momentum scattering or influence of the external field.

Another mechanism is concerning with the change of the initial and final states population as a result of the limited energy relaxation velosity of the photoexcited carriers. There are two possibility of it. The first. is "burning" of dip in the energy population $dp(\mathcal{E})/d\mathcal{E}$ ($p(\mathcal{E})$ is the number of holes with the energy $\mathcal{E}$ in the volume unit) near the energy of the initial state $\mathcal{E}_o$, which occurs because of the rate of hole ejection due to the light absorption exceeds the rate of energy relaxation in the hole system /3-6/. The second is shifting of the all population function as a result of the hole heating /2/. When $\mathcal{E}_o$ lies in the region of the rising part of the population function ,the heating of holes reduces the absorption coeffitient.

These mechanisms give rise to different dependences of absorption coefficient k on the illumination intensity I. In the Raby oscillation case we have the following for absorption coefficient.

$$k = k_0/(1+I/I_{S1})^{1/2} \qquad (1)$$

were k is the absorption coefficient at low intensity, I_{S1} is the saturation parameter associated with the dipole moment.

In the second case, the population of the initial and final states are changing, the dependence is

$$k = k_0/(1+I/I_S) \qquad (2)$$

were $I_S = 1/\sigma\tau$ is the saturation parameter, τ is the energy relaxation time, σ is the cross section for absorption of ligth by holes.

The saturation absorption of IR-FIR radiation in p-Ge was investigated in detaile in the wide spectral (10-340 μm), temperature (40-300 K) and density (10^{12} -10^{17} cm^{-3}) ranges /2-9/.

It is necessary noted that in the certain condition in p-Ge the opposite effect is obsorved :absorption increase with the increasing of ligth intensity (" darking"). There are two posibilities of the effect origine : multiphoton heavy-to-ligh hole transition /10/ and hole heating /2/. It is intresting to note that the hole heating can produce "darking" in the case when the initial energy state $\mathcal{E}_o$ of the direct intraband transition lies in the region of the falling part of the population function $dp(\mathcal{E})/d\mathcal{E}$.

Our experimental investigations /2,6,9/ have show that the situation of equation (2) is more typicall. We have studied absorption in p-Ge with hole densities from 10^{12} to 10^{17} cm^{-3}, at temperatures from 77-300 K, the wavelength being from 10 to 200 μm and intensities changing from 10 kW/cm^2 - 40 MW/cm^2 . In the case of the wavelength of order 10 μm our data obtained at room temperature can be described by equation (1) that agrees well with the resalts /4,5,8/. We think that in this case intraband multiphoton effects take place.

Some of our results obtained at different wavelength λ presents in Fig. 1 (λ =10.6 μm) and Fig. 2. (λ =90.55 μm).

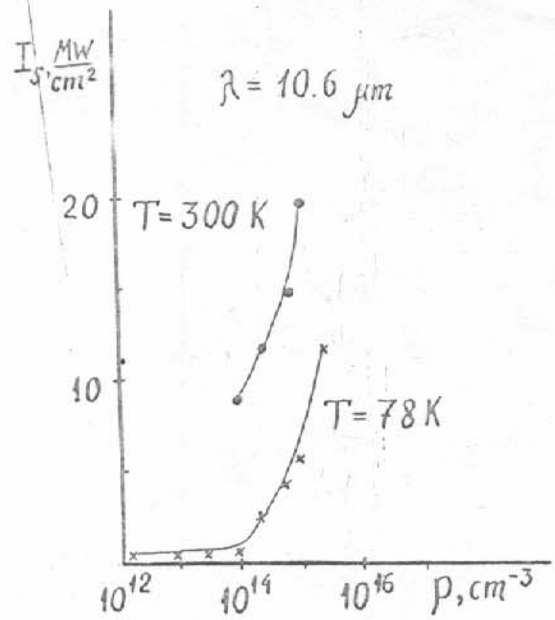

Figure 1.

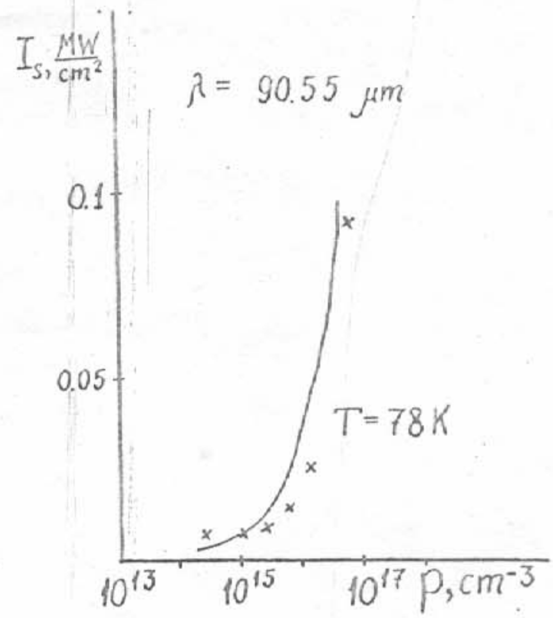

Figure 2.

It should be noted that the saturation parameter I_S can be changed in wide range by means of changing temperature and carrier densities. Saturation parameter for submillimeters range is much less than that for wavelength of CO_2 laser.

The saturation absorption has a wide practical application. It can be used to the constraction of the nonlinear optic elements in IR-FIR spectral range.

In IR range a reliable mode locking unit have been developed and studied which made it possibile to achieve stimulated emission of short pulses from a CO_2 laser /11/. In the unit hole germanium filters are used which are cooled to 78 K and feature low threshold (10-15 MW/cm^2) and short time (<0.1 ns) of bleaching. As a whole the system is capable of lasting for more than 10^5 lasing cycles without noticeable damage to anti-reflection coatings and laser elements.

The ultra low saturation intensity of p-Ge at liquid nitrogen temperature in FIR range (near 1 kW/cm^2) permits the unit for the FIR pulses shotering to be constructed. This unit has been developed and studied. It consist of the hole germanium filter which are cooled to 78K. The gause form FIR laser pulse at intensity more than 5 kW/cm^2

pass through unit decreased in 5 times approximately.

It is necessary also mentioned that the saturation absorption influence on the parameters of the semiconductor devices which used a semiconductors with the degenerate valence band. Thus, it is limited the dynamic range of photon drag /12/ and intraband photoconductivity /13/ detectors in IR region, and should decrease the losses in p-Ge FIR semiconductor lasers.

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